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THE EFFECTS OF SOUND PATTERN, INTENSITY LEVEL AND FREQUENCY ON VISUAL PERCEPTION

by

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ABSTRACT:

This paper discusses the effect of audio sound pattern, intensity and frequency on human visual depth perception and visual discrimination ability. The depth perception ability of fifteen subjects that were used in these experiments was not significantly affected by the experimental variables. Visual discrimination ability was degraded by the experimental variable of 400 cps sinusoidal sound between 80 and 110 decibels. The degradation was .205 seconds and may have an effect on human performance in situations where activity involving high speeds is present.

FOREWORD

This experimental investigation was sponsored by Paul Quinn, AIR-53365D, Naval Air Systems Command, Washington, D. C. The work was performed in the Man-Machine Systems Design Laboratory of the Naval Postgraduate School, Monterey, California.

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I. INTRODUCTION

The interest in man's pollution of his environment has shown a dramatic upward trend in the past few years and undoubtedly will continue so in the future. This report describes two experimental investigations into the effects of "noise pollution" on 1) man's ability to perceive and recognize detail and 2) on man's visual depth perception ability. As our environment becomes saturated with more noise of higher intensity levels, it is possible that the disturbances in man's audio sensory pathways may have detrimental effects on his visual sensory system via neurological and physiological pathways. If the audio and visual systems do interact with each other, and most would agree they do, then it would be of interest and value to know what are the effects of high noise levels on workers in factories, on military men in combat, on airport personnel and others who are likely to frequently encounter high levels of noise.

A search of the literature revealed little of value in finding reference sources on the effects of high noise levels on man's visual system, and this research was subsequently performed as described herein.

Since two separate investigations were carried out, Experiment I describes the effects of various noise conditions on man's visual discrimination ability and Experiment II describes the effects of various noise conditions on man's depth perception ability.

II. EXPERIMENT I

A. OBJECTIVE

The objective of this experiment was to determine the effects of the following parameters of noise source on visual discrimination ability of human subjects: 1) Intensity, 2) Frequency and 3) Pattern of the source.

B. DISPLAY

The display observed by the subjects was a 6×6 matrix of numbers which were flashed on a screen fifteen feet in front of the subject. All the numbers in the matrix were the same except for one number which the subject was to identify and report. The matrix numbers were of two types: 1) A given matrix would be solidly filled with the number 8 and the number the subject was trying to locate in the matrix was a 3, 6 or 9. The imbedded target numbers were chosen to be similar in shape to the numbers of the matrix. 2) A given matrix would be solidly filled with the number 3 and the subject would try to locate a 6, 8 or 9.

The different types of matrices were presented in a random order for various times of exposure, and the time required to locate the imbedded target number was the criteria used. Lighting in the room was approximately 50 footcandles. (See the following sections on procedure for further clarification.) Figure 1 illustrates a typical disply slide.

8 8 8 8 8 8
8 8 8 8 8 8
8 8 8 8 3 8
8 8 8 8 8 8
8 8 8 8 8 8
8 8 8 8 8 8

FIGURE 1. TYPICAL DISPLAY SLIDE

C. SOUND CHARACTERISTICS

The sounds used as experimental variables for assessing their effects on visual discrimination were:

1) Two intensity levels, 100 and 110 decibels were used since these are above acceptable noise levels but still below the pain threshold levels of hearing.

2) Three different sound frequencies were used which should be within the normal hearing range of most people. They were 250 cps., 1000 cps. and 4000 cps.

3) Three different sound patterns were presented to subjects. These patterns were: (1) A constant sound (2) A brief 1/2 second random beeping sound. (The experimental interval was split into 1/2 second lengths and an electronic random generator presented a signal in 50 percent of those intervals but on a random basis. In other words, for each 1/2 second interval, there was a 50 percent chance a beep would be presented.)

(3) An approximately 1 1/2 second continuous sinusoidal sound which alternated between oscillating up to the decibel level being used (either 100 or 110 db.) and then down about 20 db.

Therefore, when a subject was performing the visual discrimination task, he was presented, binaurally, a sound with a specific pattern, decibel level and frequency.

D. SUBJECTS

Fifteen subjects were used in the experiment. All had normal hearing in the frequency ranges used and all were military officers or professors at the Naval Postgraduate School.

E. PROCEDURE

Subjects were seated in a sound chamber, fifteen feet in front of the screen on which the number matrix would appear. The first matrix was presented for .1 seconds. If the subject did not identify the target number imbedded in the matrix, another matrix was randomly selected and presented for .2 seconds. If the subject did not identify the imbedded number in the second matrix, another matrix was presented for .3 seconds, and so on until an imbedded number was identified and the exposure time for that matrix was then recorded. This constituted one data run. Thus, exposure time to identify the imbedded target number was the dependent variable which was used to analyze the visual discrimination ability of these subjects.

Before a given subject was subjected to the noise, six data runs were taken in a silent no noise condition to obtain a baseline performance. The last four of the six runs were averaged to provide the baseline data (the first two data points were not used to avoid any possible learning effects). Once the baseline data were collected, the data runs with the binaural sounds began.

F. EXPERIMENTAL DESIGN

The 18 conditions of the visual discrimination task (2 decibel levels - 100 and 110 - by 3 frequencies - 250, 1000 and 4000 cps. - by 3 noise patterns - constant, random beeping, and continuous (sinusoidal) were presented to each subject in approximately thirty minutes. Each subject received all 18 conditions in a random order to prevent data bias. Two data points (exposure time of matrix identified) were taken for each subject under each condition for a total of 540 data points. The difference between the noise data points and the control (no noise) baseline data was taken as the data to be analyzed to determine if any of the sound combinations had a greater effect on visual discrimination ability of the subjects. Variables held constant were ambient illumination, display contrast and display size. (The matrix numbers were approximately one inch in height when projected on the display screen.)

G. RESULTS

Exposure time differences under noise and no noise conditions for recognition of the imbedded target number in a matrix were collected and analyzed with a $2 \times 3 \times 3$ repeated measures analysis of variance (ANOVA). Table I summarizes the results of the ANOVA.

The three different frequencies had a different effect on maximum exposure time. Table I indicates the chance of this happening is .005 and indicates there was a difference in the maximum exposure times between the three frequencies. Figure 2 illustrates this and

TABLE I

ANALYSIS OF VARIANCE ON

MAXIMUM EXPOSURE TIMES

Source	df	MS	F	p
Frequency (F)	2	1.40	7.38	.005
Pattern (P)	2	1.43	7.41	.005
Decibels (D)	1	.35	2.76	.25
Subjects (S)	14	.27		
F × P	4	.54	3.99	.01
F × D	2	.10	.67	NS*
F × S	28	.19		
P × D	2	.79	2.11	.25
P × S	28	.19		
D × S	14	.13		
F × P D	4	.18	.92	NS
F × P × S	56	.14		
F × D × S	28	.14		
P × D × S	28	.37		
F × P × D × S	56	.19		
Error within	270	.19		
TOTAL	539			

*NS means not significant

indicates that the 4000 cps. sound always caused more exposure time for the visual task compared to the control condition. A Duncan Multiple Range test of the frequencies showed no difference between the 250 and 1000 cps. frequencies but they were both statistically different from the 4000 cps. frequency at $p < .05$.

The pattern of the sound source also affected performance ($p < .005$) as seen in Table I and a Duncan Multiple Range test on the data indicated that the beeping pattern was different from the sinusoidal pattern ($p < .05$) in its effects on performances. There were no other differences.

The frequency by pattern interaction indicated in Table I at $p < .01$ is clearly illustrated in Figure 2 by the crossing of the 250 cps. and 1000 cps. lines. For some unknown reason, the 250 cps. frequency produced the opposite result from the 1000 cps. frequency in the beeping sound pattern condition compared to the other two noise patterns.

None of the other parameters in Table I indicated a strong statistical effect.

H. SUMMARY OF EXPERIMENT I

The results of Experiment I indicate that a 4000 cps. tone with a sinusoidal variation in amplitude (up and down every 1 1/2 seconds from approximately 80 to 110 db.) produces the worst effect on the visual system. This sound, similar to a warbling police siren, causes a decrease in visual discrimination recognition time

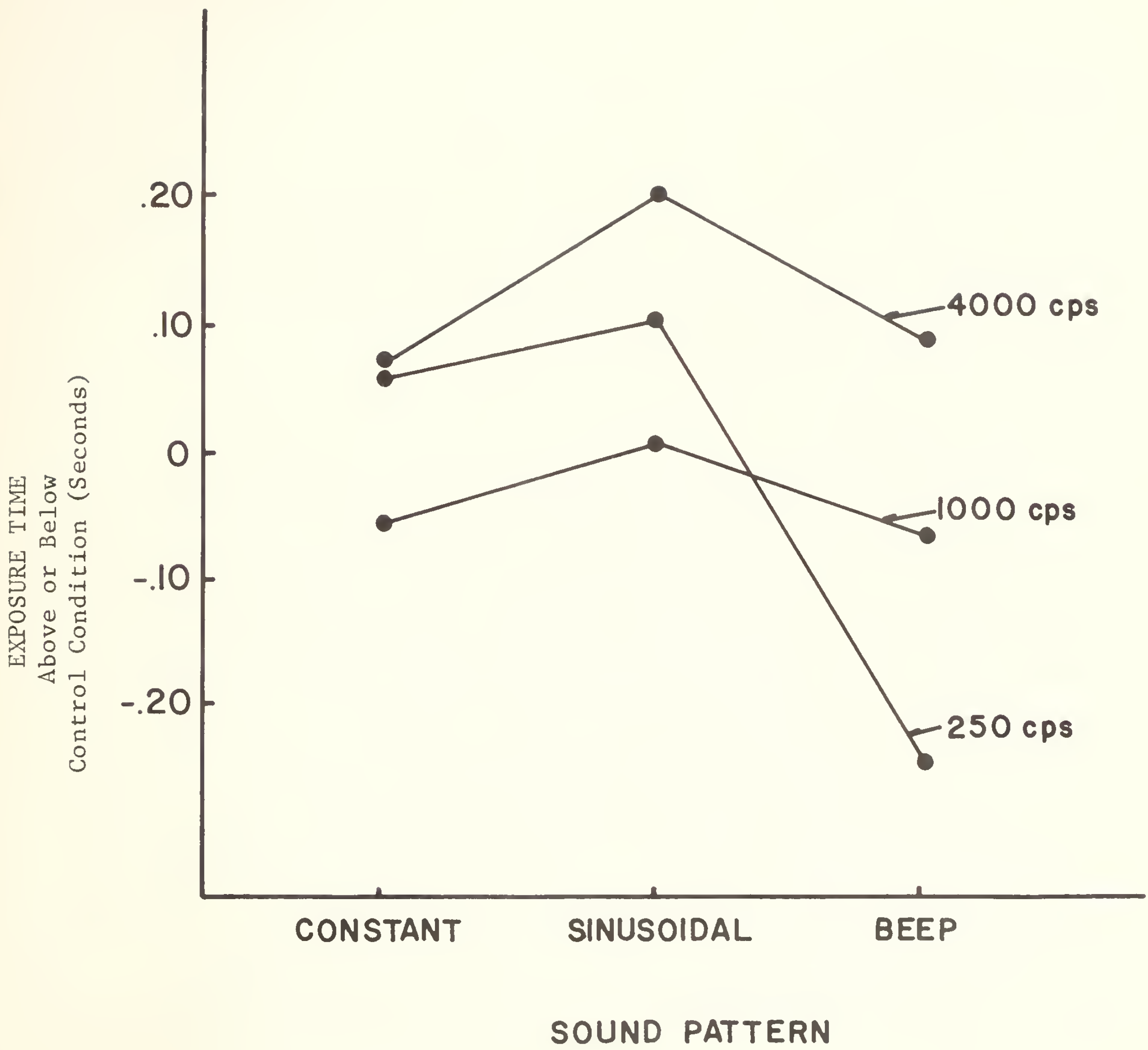

Figure 2: MAXIMUM EXPOSURE TIME VS. SOUND PATTERN

of approximately .205 seconds as compared to a baseline of no noise. Depending on the particular working environment, this decrease in recognition time could cause drastic results if high speeds of movement were involved in a particular job.

III. EXPERIMENT II

A. OBJECTIVE

The objective of this experiment was to determine the effects of the same parameters, intensity, frequency and pattern of noise source, on human depth perception.

B. DISPLAY

The display observed by the subjects was a depth perception box (Lafayette Instrument Co. #14012) which has an illuminated white background and two 3/8" black rods in front. When the subject looks into the box, he sees two vertical black rods on a white background. The subject then uses a string and pulley system to pull the rods back and forth and attempts to align the vertical rods each at the same distance from the subject. The amount of distance between the two rods, in the "depth" direction, can then be observed and recorded. At the beginning of each trial, the rods were always 8" apart in depth. Illumination of the white background was 12 foot candles.

C. SOUND CHARACTERISTICS

The sounds used as experimental variables for assessing their effects on depth perception were the same as those for Experiment I as listed on page 4. Thus, when a subject was performing the depth perception task, he was also presented binaurally, a sound with a specific pattern, decibel level and frequency.

D. SUBJECTS

The same fifteen subjects used in Experiment I were also used as subjects in this experiment.

E. PROCEDURE

Subjects were seated in a sound chamber fifteen feet in front of the depth perception display box. At the beginning of a trial, the experimentor stepped in front of the box and positioned the vertical rods eight inches apart. Then the experimentor would step aside and the subject would adjust the rods until he thought they were equal distance from him. Initially, six trials were run in a no noise condition and the last four were used as the baseline performance for the subject. The data point for each trial was the distance between the two rods, in centimeters, after the subject had adjusted them. In the sound conditions, each subject performed two trials under each combination of sound pattern, intensity and frequency.

F. EXPERIMENTAL DESIGN

The 18 conditions of the depth perception task (2 decibel levels - 100 and 110 - by 3 frequencies - 250, 1000 and 4000 cps. - by 3 noise patterns - constant, random beeping and continuous (sinusoidal) were presented to each subject in approximately 20 minutes on a different day from Experiment I. Each subject received the eighteen conditions in a random order to prevent data bias. Two data points were taken for each subject under each condition for a total of 540 data points. The difference between the no noise data points and experimental condition data was analyzed to determine if any of the sound combinations had a greater effect on visual depth perception. Variables held constant were ambient illumination, display contrast and size.

G. RESULTS AND SUMMARY OF EXPERIMENT II

The data was analyzed with a 2 × 3 × 3 repeated measures analysis of variance (ANOVA). Table II summarizes the results of the ANOVA and Figure 3 graphically portrays these results. As Table II indicates, none of the experimental variables affected depth perception to a very significant degree compared to the normal standard of $p = .05$ used by most researchers. Thus, as Figure 3 points out graphically, the experimental noise conditions used did not significantly affect depth perception ability as they did visual discrimination and recognition ability in Experiment I.

IV. CONCLUSION

Two studies describing the effects of various sound patterns, intensities and frequencies have been discussed. For the experimental variables used, depth perception ability was not affected by the variables, but visual discrimination and recognition ability was. A

TABLE II

ANALYSIS OF VARIANCE

ON DEPTH PERCEPTION ERROR

Source	df	MS	F	p
Frequency (F)	2	2.92	1.31	.25
Pattern (P)	2	1.55	.48	NS*
Decibel (D)	1	.02	.01	NS
Subjects (S)	14	1.54		
F × P	4	.94	.41	NS
F × D	2	.75	.28	NS
F × S	28	2.23		
P × D	2	4.06	2.76	.10
P × S	28	3.22		
D × S	14	1.33		
F × P × D	4	3.09	1.42	.25
F × P × S	56	2.28		
F × D × S	28	2.67		
P × D × S	28	1.47		
F × P × D × S	56	2.19		
Error Within	270	.86		
TOTAL	539			

*NS means not significant

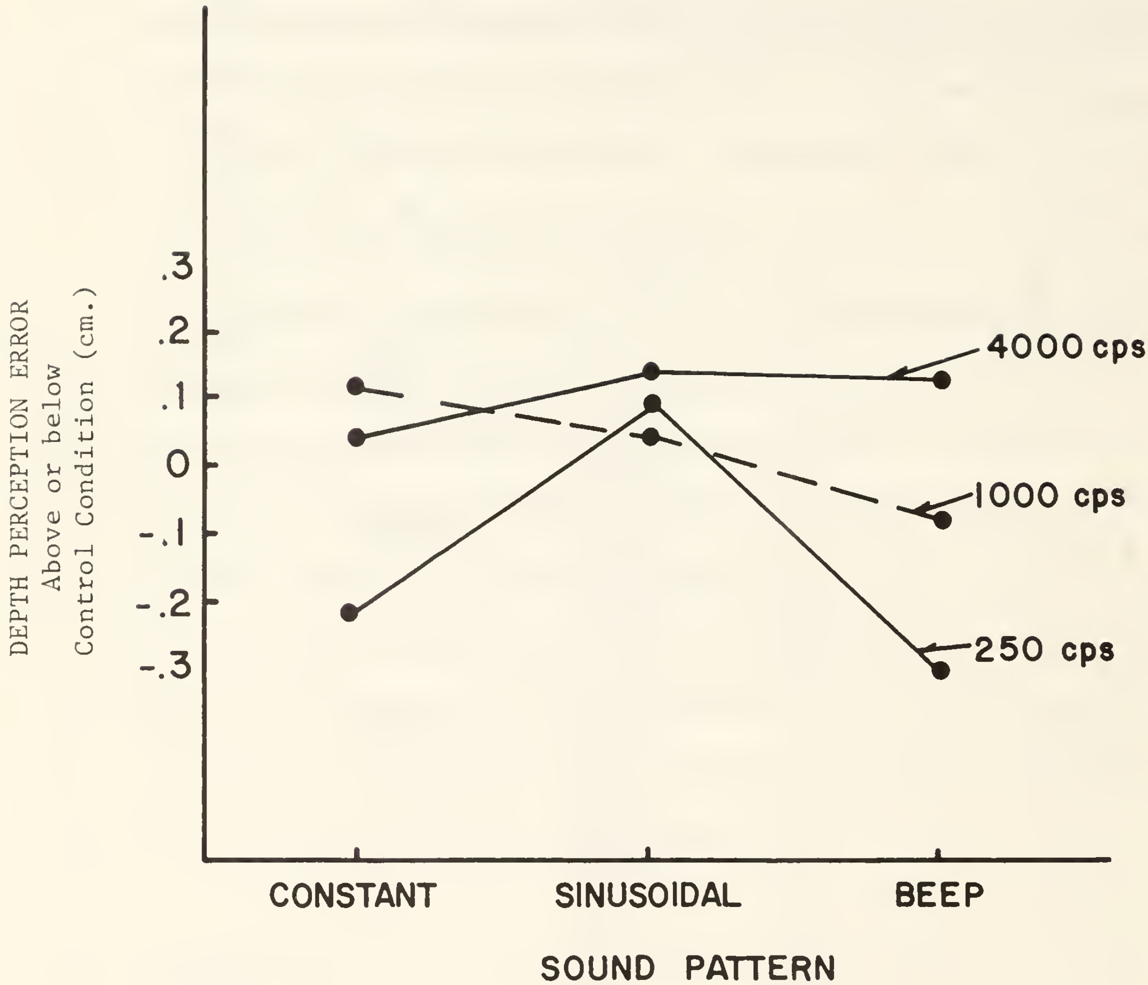

Figure 3: DEPTH PERCEPTION ERROR VS. NOISE PATTERN

4000 cps. sinusoidal tone between approximately 80 and 110 db. produced the worst degradation in discrimination and recognition ability. For people working under similar conditions, one should be aware that human performance may be affected adversely.

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